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Comments by Steven K. (Steve) Stroh requested by the Spectrum Policy Task Force of the Federal Communications Commission in the matter of ET Docket No. 02-135

Introduction

Focus **On Broadband Wireless Internet Access** is an independent newsletter that examines the companies, technologies, and developments that are creating the Broadband Wireless Internet Access industry. The first issue of ***Focus*** was published in June, 2001. I have written nearly exclusively on the subject of Broadband Wireless Internet Access since 1997 when I began the Wireless Data Developments column in **Boardwatch Magazine**. In that column, I explained to Internet Service Providers why they should be using wireless systems of various kinds to provide Internet access to their customers. I have written for a number of other publications on Broadband Wireless Internet Access and related subjects, most notably **Broadband Wireless Business Magazine** and **CQ Amateur Radio Magazine**, where I am Contributing Editor, Digital Wireless and author the Digital Wireless column. I currently live and work in the Seattle, Washington area.

Prologue

I appreciate and applaud the Commission for initiating this sweeping survey. The scope and depth of the questions clearly indicate that the Commission is keenly aware of the numerous potential approaches towards spectrum management issues. I hope the comments I have provided herein will be of use to the Commission in formulating a spectrum policy that leverages the needs and technological capabilities of the United States of the current century rather than policies more appropriate for the previous century.

I have actively and intimately participated in the microcomputer industry since approximately 1980 – approximately the beginning of the "IBM PC and DOS" era to the present. I began to study and use the Internet beginning in approximately 1984. It's my observation that the success of the microcomputer industry is that it operates largely on the model of "semi-open standards, innovation, adaptation, evolution, and consensus/cooperation… fast, Fast, FAST". My observations of the Internet suggest that the Internet's overwhelming success is due largely to open standards, the designed-in flexibility of the TCP/IP protocol that can be adapted to nearly any type of communications, and the rapid evolution of new systems and rough consensus. I feel strongly that some of the successful practices and ideas of the microcomputer industry and Internet industries can and should be applied to the ideas of spectrum management.

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It may be helpful to know that I am a licensed Amateur Radio operator (callsign N8GNJ) since the mid-80's, and my on-air activities have been largely confined to operating in the "digital" / "Packet Radio" modes, including active use of TCP/IP over radio beginning in the late 1980's.

As will be seen below, I am an unabashed and unapologetic advocate of the license-exempt spectrum model of spectrum policy. With the exception of the idea and phrase "the Darwinian Effect of License-exempt Wireless" which, to my knowledge I was the first to state and champion in my early writing, I do not claim that the ideas presented below are uniquely my own.

The ideas I present below are largely a synthesis of other people's ideas, research, and development on the subject of spectrum policy and license-exempt wireless. I couple that background with intensive observation of what is working, and what is not working in the Broadband Wireless Internet Access industry. I would specifically like to credit:

- The many companies that make amazing equipment for the Wireless ISP industry and affiliated industries that operate in license-exempt spectrum
- The Open Spectrum Project and those participating in it
- Tucson Amateur Packet Radio (of which I am currently a Board member) and their promotion of Spread Spectrum technology
- Paul Baran
- Dewayne Hendricks
- Dave Hughes
- Lyle Johnson
- Dr. Greg Jones
- Dr. Tim Shepard
- And *many* others

Commission Questions, Steve Stroh Comments

Q1. What specific policy and rule changes are needed to migrate from current spectrum allocations to more market-oriented allocations?

A1.

- The Commission's model of "spectrum as property… auction it" is fundamentally flawed. Unlike "land" or "property", spectrum is entirely a creation of advanced technology. As steadily more advanced technology is applied to the problem of "spectrum scarcity", spectrum can be used more and more efficiently, creating the same effect as if more spectrum were allocated.
- Instead, the Commission should seek to regulate spectrum as a commons; like the oceans, or the airways, or interstate highways, managing it for "the greatest good,

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for the greatest number". The Commission's current "auction" approach is equivalent to assigning dedicated shipping lanes, air traffic routes, or highways between certain cities to private entities who paid the greatest amount for that privilege, but then are able to completely exclude anyone else from using those lanes, routes, or highways at any time.

- The Commission should look closely and strive to understand the reasons for the enormous economic activity being generated by use of license-exempt spectrum versus the relatively paltry amount of economic activity being generated by licensed spectrum, specifically MMDS and LMDS bands. I posit that the primary reasons for the vastly greater economic activity in the license-exempt spectrum are:
    - License-exempt spectrum is highly flexible
    - Barriers to entry for using license-exempt spectrum are much lower
    - The market for equipment for license-exempt spectrum is much larger, resulting in more innovative products, greater quantities being produced with corresponding lower costs
- Moore's Law has entered the realm of spectrum with enormous advances in digital signal processing technology and advanced, inexpensive radio frequency components. Coupled with abundant, inexpensive memory and vast computational power available in current generation microprocessors, wireless technologies that were previously impractical for commercial use such as phased array antennas, adaptive modulation, and software-defined radio are now feasible, and soon enough, widespread and inexpensive.
- In deciding policy, the Commission should "bet towards the future" and embrace Moore's Law rapidly expending influence in wireless technology. "Smart" wireless devices are able to make spectrum utilization decisions in microseconds versus the equivalent human decision-making process taking years. For example, the Commission should begin reallocating television spectrum now, but on a license-exempt basis, with the requirement that any wireless devices that make use of television spectrum "listen" for television broadcasting so that the wireless device will not transmit on any channel in which it "hears" television broadcasting. This will allow the very valuable television spectrum to be used in areas (such as rural) where such new wireless systems will not interfere with television broadcasting.
- The Commission should also embrace the lessons found in David Isenberg's essay "The Rise Of The Stupid Network" – that the best network, or in this case, the best allocation of spectrum, is one in which the end nodes, or in this case, wireless devices, "make the decisions". If a consumer wishes to transmit video from one house in a neighborhood to another, they should be able to buy the appropriate wireless video units and assume that the units themselves will "work it out" which spectrum is most appropriate for the intended use, what power levels are needed for adequate signal, whether a relay point is needed or not, etc. The "spectrum" or the Commission's allocation or rules for spectrum shouldn't care

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how the spectrum is used… just minimal "rules of the road" designed to insure cooperation, sharing, and efficient usage.

Q2. Should current, restrictive service and operating rules applicable in many bands be changed to provide licensees with greater flexibility? If so, in which bands and how?
a. Should incumbent users be given flexibility within their existing spectrum?
b. Should "site" licenses (e.g., broadcasting, private land mobile) be converted to geographic area licenses? If so, how should such licenses be defined (e.g., by power limits at geographic and frequency boundaries)?
c. How should spectrum not currently licensed by geographic areas be assigned or re-assigned, e.g., by auctioning Commission-defined "overlays" or by other means?
d. What are the relative efficiencies and inefficiencies of different licensing models?
e. How would the interference rights of incumbents and new licensees be redefined under flexibility?
f. What, if anything, should the Commission do to facilitate efficient restructuring of spectrum held by new licensees and incumbents, i.e., reduce transactions costs, avoid strategic holdouts, and create greater certainty about costs?

A2.

- Except for public safety and critical systems (fire, police, law enforcement, aviation) spectrum allocations should be gradually migrated to a license-exempt model with the relevant regulatory policies to be "embedded" in the radios. A license-exempt model allows the spectrum to be used flexibly, efficiently, where needed, as needed, and for the spectrum usage to evolve over time as new devices with different characteristics are purchased and used. Human decisions about specific spectrum, geographic, usage, technical (power, mode) would no longer be required.
- A prime example is the enormously cumbersome process necessary to activate new systems in the ITFS/MMDS band. The current, major licensees of ITFS/MMDS spectrum, and many smaller licensees have largely failed to make effective use of the majority of the ITFS/MMDS spectrum in the vast majority of potential service areas. The Commission should implement "immanent domain / for the public good" procedures to reclaim ITFS/MMDS spectrum in much the same way land was procured to build the Interstate Highway System (including reasonable compensation to the land [spectrum] owners.)
- To fund the operations of the Commission and compensate for potential revenue to the US Treasury lost from potential spectrum auctions, the Commission should levy a minimal (*very* minimal) "spectrum use tax" on each wireless device sold in the US. Doing so would encourage the formation of wireless systems and the subsequent purchase of more and more wireless systems, with revenue generated based on the success of the system rather than a "front-loaded" burden of payment.

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Q3. Should spectrum policy be different in different portions of the spectrum or in different geographic areas?
a. For instance, should the more congested region of the spectrum (i.e., that below 3 GHz) be governed by different policies than the less congested portions of the spectrum? Should different licensing concepts be applied to upper millimeter wave spectrum where propagation characteristics limit the range and small wavelengths enable very narrow beams?
b. Should spectrum policies vary by geographic area according to the relative level of spectrum congestion or use? For instance, should the rules be different in urban areas where spectrum is generally in high demand, than in rural areas where the demand for spectrum is typically low, or in the transition areas – where spectrum demand is somewhere between high and low demand regions?
c. How can spectrum use, congestion and demand be accurately measured and predicted?

A3.

- As above, spectrum policy should be "embedded in the radios" and it is left up to the radios to "flexibly decide" how/when the policies should be applied. For example, if a "spectrum policy embedded radio" were to "hear" excessive interference as would result in a dense urban environment, an "embedded spectrum policy" (embedded in *all* radios) may be that power output should be reduced (and *all* radios experiencing excessive interference would do so) to allow the dense deployment of radios to all continue to operate. In a rural area, with the radio hearing "no significant interference", the "embedded spectrum policy" may well dictate that a much greater power level can be used.
- Spectral properties and current state of engineering should dictate how each part of the spectrum is used to allow use of the spectrum to evolve as wireless technology evolves without requiring the Commission to "manually" sanction each new use.

Q4. Are there circumstances under which adopting more market-oriented allocation and assignment policies would affect other important Commission objectives? For example, could the optimal provision of radio services to or by public safety and public service entities be helped or hindered by more market-oriented spectrum policies? Are there specific market failures that would produce such adverse affects, and what should the Commission do to address these market failures?

A4.
Because lives are at stake, public safety uses of spectrum tend are intolerant of "goofs" such as would result from an "embedded spectrum policy" radio mistakenly "deciding" that a public safety band is "vacant" and it's permissible to transmit there. "Goofs" in the initial development and implementation of "embedded spectrum policy" radios are unavoidable; no human technology is perfect. It's not possible to anticipate every conceivable failure mode except with the yardstick of long experience. For that reason,

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"embedded spectrum policy" radios should be programmed to "avoid at all costs" transmitting in certain portions of spectrum that is used for public safety purposes. Such a prohibition should have a sunset clause of some years as the "embedded spectrum policy" radio technology is developed, widely deployed, experience is gained, the technology is advanced. A few years into the future, "embedded spectrum policy" radios will have evolved to the point of being "trusted" to "choose well" whether or not to transmit and not interfere with public safety communications.

Q5. Should more spectrum be set aside for operating unlicensed devices? Should the kinds of permissible unlicensed operations be expanded? What changes, if any, should be made to the rules to accomplish this? Because of the commons aspects of unlicensed use, is there concern that, as congestion rises, spectrum may not be put to its highest valued use? If so, what policies might be considered to anticipate this problem?

A5.

- As discussed above, the license-exempt model should be applied to nearly all spectrum. The Commission's Part 15 rules contain a key operational requirement which is, in my opinion, *brilliant* in its inception, and *the fundamental reason* why so much economic activity is being generated in relation to the license-exempt bands. This key operational requirement is that *each license-exempt device "… must accept interference, even if such interference causes undesirable operation."*
- This operational requirement means that continued operation is not guaranteed and by extension, *no* particular use, *no* particular system, *no* particular user or group of users can "veto" a new use of license-exempt spectrum by complaints about "interference". I've come to describe this effect as "The Darwinian Effect Of License-exempt Wireless." Users that wish to continue to use license-exempt spectrum must "continually evolve" their usage of the spectrum through the purchase of steadily more sophisticated, more robust systems, better engineering, and other techniques. In short, with the "… must accept interference…" operational requirement, *progress in license-exempt spectrum cannot be stopped*.
- The Commission should strengthen its labeling requirements and its public education programs to more clearly convey a strong, unambiguous message that *any* system that makes use of license-exempt spectrum does not and can not offer absolute protection against interference. Rather consumers should "vote with their wallets" and purchase only well-performing, license-exempt technology, likely with guidance on which systems perform well provided by entities such as Consumer Reports. In practice, this does happen in cases where an inexpensive 900 MHz cordless phone is too susceptible to a nearby high-powered paging transmitter, and is returned to the store for a different model.

Q6. How can the Commission better facilitate the experimentation, innovation and development of new spectrum-based technologies and services through, for example,

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changes in its experimental licensing rules, increased use of developmental authorizations or promoting demonstration projects?

A6.

- As outlined above, the ultimate goal of the Commission should be to evolve toward a license-exempt, "spectrum policy embedded in the radios" model, but such an evolution will take time to phase in. In the interim, the Commission can indeed make changes to facilitate development as implied in the question.
- The Commission should liberalize the granting of Special Temporary Authority (STA) licenses for reasons other than technical experimentation. For example, an STA could be requested by a Wireless ISP to evaluate the usage of ITFS/MMDS equipment in their market.
- In the case of a spectrum holder demonstrably not making use of a spectrum allocation, the Commission should develop a "use at your own risk" license that, for example, would allow a Wireless Internet Service Provider (WISP) to use ITFS/MMDS spectrum in a small market that a large spectrum holder is highly unlikely to actually deploy equipment in. If the WISP is willing to "gamble" an investment to use spectrum that they may be "evicted" from using, then they should be allowed to do so (with the proviso that the "gambler" have no recourse whatsoever if the spectrum holder does finally deploy a system in that market.)
- The Amateur Radio Service is the *original* radio service regulated by the Commission and has traditionally been used by experimenters to develop new techniques, technology and systems that were later deployed in the commercial wireless industry. The history of Amateur Radio is rich with examples of "it was tried first on Amateur Radio". However, in the last several decades, the Commission's policies (often at the behest of the American Radio Relay League - ARRL) have served to discourage experimentation in the Amateur Radio service. For example, despite the 30 MHz of spectrum available in the US Amateur Radio 420-450 MHz band, in almost every urban area, almost the entire 30 MHz is allocated to voice repeater systems using technology that was last state-of-the-art in the 1950's! Such technology, despite its antiquity, should certainly be *permitted* in the Amateur Radio bands, but *not protected at the expense of preventing experimentation in the same band*. The Commission should remove provisions in the Amateur Radio rules that "enable" such fossilization of older uses at the expense of experimentation. The Amateur Radio service should be redirected back to its core mission as an experimental service, with only a very small part of Amateur spectrum reserved for "stable, operational uses." The Commission will clearly recognize that the ARRL and many older Amateur Radio operators will protest such changes, but the Commission must weigh the benefits to society as a whole in encouraging a more vibrant, progressive, and experimentation-oriented Amateur Radio service against the protests of a relative few existing Amateurs that "… like things just the way they are because *I've* got *my* repeater already coordinated."

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Q7. Are new definitions of "interference" and "harmful interference" needed? If so, how should these terms be defined?

Q8. What is the impact, if any, of increased flexibility on how harmful interference should be defined and understood?

Q9. Are more explicit protections from harmful interference of incumbent users required?

Q10. Does defining power limits (in-band and at service area boundaries) and coordination procedures in the Commission's rules provide sufficient control over interference as new uses are introduced by licensees? What other regulatory measures are needed, if any?

Q11. Does defining power limits and other measures in the Commission's rules designed to protect against harmful interference affect innovation?

Q12. As technology advances, should what the Commission defines as unacceptable or "harmful" interference correspondingly change in the future? How should rights and obligations of spectrum users be defined to facilitate such changes as well as innovation?

Q13. If the Commission adopts new policies to address interference, should the rights of new spectrum users be defined differently from those of the present incumbents? If yes, how?

Q14. Should the Commission consider developing receiver standards or guidelines for each radio service that would be used in judging harmful interference? For example, should such standards or guidelines aim to protect receivers that meet or exceed the standards or guidelines, but allow users to use less robust receivers at their own risk? If so,
a. What criteria should be considered in drafting these standards/guidelines?
b. How should the Commission consider protecting legacy receivers?
c. Should these standards/guidelines differ among the various radio services

Q15. In lieu of, or to complement, technical rules related to interference, are there processes that the Commission could consider that would allow private parties to more expeditiously resolve interference issues and disputes, for example, through negotiated agreements, mediation, arbitration or case-by-case adjudication?

Q16. Some parties assert that the Commission should adopt rules for interference that are based on economics, and not purely technical, in nature. They argue that efficient interference management should involve an economic balancing between the parties using the spectrum. Would greater use of these types of alternatives lead to more certain and expeditious resolution of interference issues?

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A7-A16.

- As described above, in the evolution towards license-exempt operations, "spectrum policy embedded in the radios" model, the Commission should continue to prioritize existing operations and continue to authorize secondary uses of spectrum such as it has done with Ultra Wideband operations.
- As above, there should be substantial "protection" provided in the "embedded policies" of license-exempt radios for public safety communications for an interim period as the "embedded policy" radio technology evolves.
- The only meaningful measure of interference should be if a secondary use substantially (and provably) impacts communications of a primary use of spectrum. Secondary uses should not be pre-empted because of the potential to interfere, but rather only on substantial (and provable) *actual* interference.
- Going forward, the Commission's model, as much as practicality dictates, should be the "interference model" used in license-exempt operations; leaving it to the users, vendors, and operators to sort out interference issues amongst themselves *as proves necessary*.
    - A recent example was the looming potential for interference resulting from Bluetooth devices being operated in close proximity to 802.11b devices. The Bluetooth standard was modified to implement "adaptive hopping", which elegantly and cost-effectively negates the problem. The Commission only had to become involved in the issue to liberalize the license-exempt rules to allow the change to be implemented. Given the ability to implement such changes by liberalized Commission policies, the users, vendors, and operators will likely reach such accommodations rapidly because market forces motivate them to do so.
    - Interference is generally specific to location. Commission policies enacted to reduce the potential for interference between Nextel and public safety systems in dense urban environments such as New York City are hardly relevant when applied equally to Nome, Alaska. New York City has very real interference problems, and those problems should be resolved in the context of what works to resolve interference issues in New York City.

Q17. What mechanisms or policies might be considered as a means of promoting a proper level of spectral efficiency either through regulatory mandates or economic incentives? Are there mechanisms that other countries use that should be applied in the United States as well?

A17. In any "contest" of which use of spectrum is "best", maximizing the ratio of bits / Hertz / square meter / second should be a stated goal. To date, spectrum efficiency has generally not taken into account the spatial dimension or the time dimension of spectrum usage.

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Q18. Do any existing Commission rules inhibit efficient use of the spectrum? If so, how should they be changed?

A18.
Unfortunately, *most* Commission rules inhibit efficient use of the spectrum, primarily by assigning it to specific entities or particular uses. As described above, moving to a license-exempt model for most spectrum would likely permit vastly more efficient use of spectrum.

Q19. What new technologies exist that, if deployed, could improve spectral efficiencies and utilization? What are the barriers to their deployment?

A19.
Triton Network Systems developed the Invisible Fiber line of 38 GHz radios. What was remarkable about these radios was that they had fully automatic, fully dynamic, "rain region aware" power control. The power control was so exceptional that it was possible to continuously reuse a single 38 GHz channel within a single market. The dynamic power control was in marked contrast to typical 38 GHz microwave radios that had, at best, semi-dynamic power control that "polluted" paths by transmitting power in excess to what was required to maintain a high-quality link in varying conditions. Triton Network Systems is no longer in business; it was unable to compete with less-expensive, less-capable 38 GHz radios largely because there was little incentive for spectrum holders to be conservative in their use of spectrum; they "owned" the entire band, so "wasting" channels and paths wasn't an issue for them.

Carrying the dynamic power control idea a step further, Caly Networks was developing a line of 28 GHz radios that would use spectrum even more efficiently by integrating a phased array antenna, and a master transmission scheduling system. The result of Caly's technology would have been that spectrum would only be "used" on the path needed to transfer that particular piece of data *and* only for the duration of the data transmission. During the time one transmitter was transmitting, the scheduling system would "hold off" other transmissions that could potentially interfere. Caly Networks has ceased operations while still in the development stage.

These are just two of many, many examples of far, far more efficient spectrum usage made possible with new ideas, old but formerly impractical ideas, and new and rapidly evolving technologies.

Q20. Should the Commission consider ways to quantify or benchmark spectral efficiency in a way that permits fair and meaningful comparisons of different radio services, and if so, how would such comparisons be used in formulating spectrum policy?
a. How could the Commission define and quantify spectral efficiency?
b. How could the Commission meaningfully compare efficiencies across different radio services?

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c. Should spectrum efficiency be analyzed subjectively as opposed to quantitatively? If yes, how?
d. To what extent should any rules, standards or guidelines regarding spectral efficiency take into account the relative scarcity of different uses and different geographic areas as well as the cost of spectrum-conserving technologies?
e. What data and other information is necessary for the Commission to evaluate spectral efficiency?

Q21. How, if at all, can the Commission provide incentives for operators to use spectrum efficiently? For example, how could to the implementation of fees (e.g., on the basis of Hz per square mile per minute or Hz per population coverage) or receiver standards affect spectrum efficiencies?

A20, A21.
As described above, moving to a license-exempt spectrum allocation model will "level the playing field" between various users of various spectrum. In such a scenario, the most spectrally efficient technology would tend to (but not a given) win in the marketplace because it will provide better quality services, cause (and be less susceptible to) interference, at a generally lower cost.

Q22. What mechanisms can be developed to ensure the availability of dependable, interoperable and cost-efficient radio-based and other Communications services among local and state public safety and federal government agencies in their use of spectrum for public safety, law enforcement, homeland security, and critical infrastructure protection?

Q23. Recognizing that many of these special needs for communications capacity are highly variable in time and location but generally low in average traffic level, should the Commission and these users consider novel sharing mechanisms for such spectrum that might be appropriate and what criteria (e.g., very high reliability) would need to be used to determine whether such sharing is advisable?

Q24. How should the amount of spectrum dedicated for the support of public safety and related functions be determined?

A22 – A24.
As described above, to insure the reliability of public safety communications in a migration to license-exempt spectrum allocation model, public safety spectrum should, for a time, be exempted with a general move to a license-exempt spectrum allocation model.

In a gradual evolution of integrating public safety, commercial, personal, etc. communications services, public safety communications could be given "priority status"… in essence, an "override flag" that allows public safety communications to have priority over spectrum usage that's normally used for routine commercial or personal

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communications. In that way, public safety communications would have access to needed spectrum in an emergency situation, without requiring a static "unneeded most of the time" spectrum allocation.

Q25. What role should international/global considerations play in spectrum policy in the United States? And conversely, how should U.S. preparations for regional and international meetings on spectrum policy take into account domestic spectrum policy decisions?

A25.
International spectrum allocation considerations should be a factor, but not a dominant factor. It used to be the case that economies of scale in the production of wireless devices strongly favored an internationally-unified approach for spectrum allocations. Soon enough, wireless devices will be highly configurable using approaches like Software Defined Radio (SDR) where spectrum usage, modulation techniques, and feature set will be downloaded as needed.

Q26. How should the requirements for international coordination of satellite systems affect the U.S. assignment of satellite orbits *and frequencies for domestic and international service?*

A26.
While Geosynchronous Earth Orbit (GEO) satellite allocations can be localized and regionalized to some extend due to their ability to restrict their coverage areas, new generations of satellites that are in non-geosynchronous orbits such as Low Earth Orbit (LEO) must, by the nature of physics of orbital paths, be coordinated internationally.

The Commission should be increasingly aggressive about reclaiming satellite spectrum allocations from entities that procure satellite spectrum allocations but fail to build out systems and services as promised when the spectrum is allocated.

Q27. Does the International Telecommunications Union (ITU) spectrum allocation process, as codified in the ITU Radio Regulations, facilitate or impede development of domestic spectrum policies?

A27.
The ITU is a typical international bureaucratic body with the typical bureaucratic failings (slow to act, etc.), but for purposes of reasonable international cooperation, it is hard to conceive of an effective alternative structure for international spectrum allocation.

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Q28. Are there ways in which the Commission can or should improve the coordination process with Canada and Mexico? If so, how?

A28.
Ideally, spectrum allocations should be harmonized in all of North America to create the spectral equivalent of the North American Free Trade Agreement. Unfortunately, this seems unlikely – Canada's spectrum allocation policies are more progressive, and Mexico's spectrum allocation and enforcement policies are more lax than that of the Commission… it would be very hard to synchronize the spectrum policies of the three countries

General, Unsolicited Comments

It is my observation that the Commission, as a whole, seems to have only the haziest idea of how much use is being made of the relatively small portions of spectrum allocated as license-exempt.

Despite the severe technical limitations inherent in use of license-exempt spectrum, individual entrepreneurs, using equipment from technically innovative equipment vendors, are making highly-effective use of license-exempt spectrum to provide needed services such as broadband Internet access in rural communities. Many are using license-exempt spectrum in urban areas as well to provide competitive telecommunications services.

The Commission clearly did not intend, at least initially, that license-exempt spectrum would be used for providing wide-area networks, or revenue services. But increasingly, it is through the use of license-exempt spectrum that the new services envisioned by the 1996 Telecommunications Reform Act are becoming reality.

The Commission should endeavor to understand and embrace, at its core, the trend towards smaller (*not larger*), innovative providers of telecommunications services including individual entrepreneurs, municipal governments, economic development organizations, and individual enterprises to better enable such innovation. In the years since the 1996 Telecommunications Reform Act, it's become apparent that the innovations in telecommunications that Congress sought to foment will not happen if left solely to the giant telecommunications companies. It's equally apparent that the desired innovations in telecommunications are in fact occurring, but on a smaller scale and in different form than the Commission was prepared to recognize. The Commission needs to "listen to the technology" that has in past decades enabled vast personal choice in microcomputer technology, Internet communications, mobile telephony, and now, in its infancy, beginning to enable flexible, *personal* wireless broadband communications.

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